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Emergency department crowding and risk of preventable medical errors

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Abstract The objective of the study is to determine the association between emergency department (ED) crowding and preventable medical errors (PME). This was a retrospective cohort study of 533 ED patients enrolled in the National ED Safety Study (NEDSS) in four Massachusetts EDs. Individual patients' average exposure to ED crowding during their ED visit was compared with the occurrence of a PME (yes/no) for the three diagnostic categories in NEDSS: acute myocardial infarction, asthma exacerbation, and dislocation requiring procedural sedation. To accommodate site-to-site differences in available administrative data, ED crowding was measured using one of three previously validated crowding metrics (ED Work Index, ED Workscore, and ED Occupancy). At each site, the continuous measure was placed into site-specific quartiles, and these quartiles then were combined across sites. We found that 46 (8.6%; 95% confidence interval, 6.4–11.3%) of the 533 patients experienced a PME. For those seen during higher levels of ED crowding (quartile 4 vs. quartile 1), the occurrence of PMEs was more than twofold higher, both on unadjusted analysis and adjusting for two potential confounders (diagnosis, site). The association appeared nonlinear, with most PMEs occurring at the highest crowding level. We identified a direct association between high levels of ED crowding and risk of preventable medical errors. Further study is needed to determine the generalizability of these results. Should such research confirm our findings, we would suggest that mitigating ED crowding may reduce the occurrence of preventable medical errors.

Keywords Emergency services · Crowding · Medical errors

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Introduction

Emergency department (ED) crowding is a major issue facing emergency care today. Aside from the inconvenience of delays in care associated with crowding, crowding has also been associated with adverse clinical outcomes [1, 2]. As a result, much effort has been made at local, state, and national levels to address ED crowding [1]. However, as the number of ED patients continues to rise and the number of EDs declines, the crowding problem worsens [3].

If we are to reduce the adverse clinical outcomes associated with crowding, a full understanding of the reasons

behind this phenomenon is necessary. Delays in care, often attributed to ED crowding, have been associated with decreased quality of care and poor outcomes [1, 2, 4–9]. Critically ill patients who remain in the ED for greater than 6 h after a decision to admit them to an intensive care unit are at increased risk of adverse outcomes and other studies associate ED crowding with increased mortality [1, 10–12]. Pines et al. [13] demonstrate an association between ED crowding and the risk of adverse cardiovascular outcomes in patients with chest pain, although the majority of these adverse outcomes occurred >24 h after patient arrival, and the association could not be directly explained through any measurable ED-based intervention or ECG timeliness. Another study describes adverse events in patients boarding in an ED, while not attributing a direct cause [14].

As it is known that a large number of medical errors occur in the ED, and numerous factors contribute to these errors; the nature of the association between ED crowding and adverse outcomes may be greater than just delays in care [15–17]. While delays in care play an important role, we hypothesize that at least part of this association might be attributed instead to preventable medical errors (PMEs) occurring during times of crowding.

Methods

Study design and setting

This was a retrospective cohort study in four teaching hospitals in metropolitan Boston that participated in the National ED Safety Study (NEDSS) [18]. Three of the hospitals are urban, while one is suburban. The urban hospitals serve as base hospitals for emergency medicine residency programs. Annual patient volume amongst the EDs ranged from approximately 50,000 to 80,000. The study was approved by each hospital's institutional review board.

Selection of participants

Participants were any patient included in the NEDSS study. These were patients presenting to the ED with a principal ED or hospital discharge diagnosis in one of three diagnosis groups: acute myocardial infarction (AMI), asthma exacerbation, or dislocation in 2004, as identified by International Classification of Disease, Ninth Revision (ICD-9) codes from hospital administrative records. These conditions were chosen because they present commonly to EDs, they are diverse, representing medical and surgical conditions affecting both men and women, and national guidelines exist for their care [19–21]. Compliance with those guidelines has been reliably assessed previously and failure to comply with those guidelines resulting in errors has been previously documented [22–28]. Exclusion criteria for each condition were explicitly defined. Patients under the age of 14 were excluded for asthma and dislocations, while those over age 54 were excluded for asthma, and those over age 89 were excluded for AMI and dislocations. Patients transferred from the ED were also excluded.

The participants represent a random sample (up to 70 for each condition) of all the patients who presented to the ED during calendar year 2004 with those conditions. When a single patient had multiple ED encounters for the same condition, only the first ED visit was included [18].

Methods of measurement

Adverse events

The outcome of interest was the presence or absence of a PME. NEDSS used a rigorous methodology to collect a sample of adverse medical events for the three diagnostic groups from 62 US hospitals [18]. Trained investigators abstracted charts for up to 210 randomly sampled ED patients per institution, with 70 from each diagnostic group. For each chart, these abstractors first determined whether an adverse event occurred based upon explicit criteria, and then determined if the event had significant potential for injury. These charts were then reviewed by two physician reviewers (either emergency medicine physicians or physicians with patient safety expertise). These physicians reviewed the potential events, and could identify additional events that were missed by the abstractors. Only if these two physicians agreed that the event either caused harm, or was significant enough to potentially cause harm, was it included in the dataset. Disagreements were adjudicated by the NEDSS investigators.

Safety-related events were then divided into four categories: non-preventable adverse events, preventable adverse events, non-intercepted near misses, and intercepted near misses. The latter three categories represent potential PMEs, and were the primary outcome for the present study—i.e., PMEs = preventable adverse events + non-intercepted near misses + intercepted near misses. Near misses were defined as errors with potential to cause injury but that did not because of specific circumstances, patient characteristics, chance, or because the error was intercepted before the injury occurred [18]. Examples of these events are provided in Table 1.

Crowding data

The exposure of interest was ED crowding. In each institution, basic administrative data were collected at 10 min

Table 1 Examples of preventable medical errors by type

Preventable AE: an injury resulting from a medical error.
Examples:

1. Initial ECG showed STEMI but no mention in physician notes; cardiac treatment delayed for several hours → cardiac arrest, death
2. Nitroglycerin given to patient who reported recent use of sildenafil → severe hypotension for 2 h, required IV fluids
3. Patient given both beta-blocker and calcium-channel blocker → severe hypotension, required IV fluids
4. Third dose of metoprolol given to an already bradycardic patient → worsened bradycardia and hypotension, required IV atropine
5. Patient given heparin, reteplase, eptifibatide and enoxaparin at same time → developed upper GI bleed, with major drop in hematocrit
6. Hyperglycemia prompted multiple insulin doses and initiation of insulin drip → developed hypoglycemia, required IV D50 solution
7. Patient given rapid transfusion of packed RBCs to correct minor anemia → onset of acute heart failure, required intubation
8. ETT placed but had negative $C0_2$ test 15 min later → new ETT placed ~20 min after initial ETT placement
9. Not given any corticosteroids for serious asthma exacerbation → returned to ED within 24 h for worsened exacerbation, hospitalized
10. Patient given large doses of midazolam and fentanyl at same time → became hypoxic and obtunded; required flumazenil and naloxone

Non-intercepted near miss: a potentially harmful error that unexpectedly does no detectable harm, due to patient characteristics or chance, despite reaching the patient.
Examples:

1. IV nitroglycerin ordered without BP "hold" parameters → given without apparent harm
2. Sublingual nitroglycerin ordered for patient on sildenafil → given without apparent harm
3. Aspirin ordered in patient with history of aspirin allergy → given without apparent harm
4. Aspirin 81 mg × 4 ordered → given only 81 mg without apparent harm
5. Beta-blocker ordered in patient with cocaine-induced chest pain → given without apparent harm
6. Heparin 4,000 unit bolus ordered → given 8,000 unit bolus without apparent harm
7. IV D50 ordered in patient with blood glucose 703 mg/dl → given without apparent harm
8. Patient with markedly elevated blood glucose was not given insulin → no apparent harm
9. Zosyn (piperacillin + tazobactam) ordered in patient with history of penicillin allergy → given without apparent harm
10. Patient on digoxin given gatifloxacin (which may increase digoxin level) → no change in digoxin level

Intercepted near miss: a potentially harmful error that is intercepted before reaching the patient.
Examples:

1. Nitroglycerin paste ordered twice (unintentional) → intercepted, second ordered deleted
2. Nitroglycerin ordered for patient on sildenafil → intercepted, nitroglycerin not given
3. IV nitroglycerin ordered without BP "hold" parameters → intercepted, hold parameters added before initiation
4. Beta-blocker ordered for patient with severe bradycardia → intercepted, beta-blocker not given
5. Beta-blocker ordered in patient with cocaine-induced chest pain → intercepted, beta-blocker not given
6. IV metoprolol 50 mg ordered (trailing zero error) → intercepted, 5 mg given
7. Albuterol nebulizer ordered 5 mg q3 → intercepted, order corrected (q20 min × 3)
8. Penicillin ordered for penicillin-allergic patient → intercepted, penicillin not given
9. MSO4 written instead of morphine sulfate → intercepted ("not magnesium"), correct medication given
10. Fentanyl dose written as mg (not mcg) → intercepted, correct dose given

ECG electrocardiogram, *STEMI* ST-elevation myocardial infarction, *IV* intravenous, *GI* gastrointestinal, *RBC* red blood cell, *ETT* endotracheal tube, *ED* emergency department, *BP* blood pressure

or more frequent intervals throughout 2004. These data were not uniform across the institutions, and precluded the use of a single crowding measure. To accommodate these site-to-site differences in available administrative data, ED crowding was measured using one of three previously validated crowding metrics: the Emergency Department Work Index (EDWIN), the ED Workscore, and ED Occupancy [29–32]. These metrics are comparable in their measurement of ED crowding [33]. Using these data, we calculated a near-continuous (every 10 min) crowding score for each enrolled patient. At each site, this continuous measure was placed into site-specific crowding quartiles, and these crowding quartiles were then combined across sites. As there is no accepted definition of an uncrowded ED, the first crowding quartile (representing the least crowded state) was defined as the crowding reference (control) group.

As NEDSS did not determine the exact time an adverse event occurred during an ED visit, we focused on the average crowding exposure during a patient's visit. Where there were missing data (e.g., patient's disposition time not documented on the chart), the crowding exposure as

measured at the first recorded time on the patient's ED encounter record was calculated and used in lieu of average crowding data.

Data collection and processing

The NEDSS database provided patient demographic characteristics (age, gender, non-English language), diagnosis group (MI, asthma, dislocation), site of care (4 participating EDs), and the type of error(s) that occurred during that patient's encounter, if any. The data elements required for calculating a crowding score at any point in time (e.g., number of patients registered in the ED, numbers of physicians and nurses treating patients, patient acuity scores) were obtained from archived data from the participating institutions' patient tracking systems.

Primary data analysis

Data were analyzed using STATA 11.1 (StataCorp LP, College Station, TX) and summarized using basic descriptive statistics. We used multivariable logistic regression analysis to determine the association between quartile of crowding and PMEs, with adjustment for clustering by site. Given the relative scarcity of outcomes, we decided a priori that the primary analysis would include the crowding exposure, outcome (PME or no PME), diagnosis group, and site. Secondary analyses addressed potential differences in the relation of crowding to specific types of PME.

Results

Characteristics of study subjects

Of 533 patient encounters across the four sites, 29 (5%) were missing either the date or time of patient disposition; as noted above, the crowding score from these patients' first recorded time in the ED was used in lieu of the average crowding score. A least one PME occurred in 46 of the 533 visits [8.6%; 95% confidence interval (CI) 6.4–11.3%]. As noted above, each of these PMEs was deemed by two physician reviewers to represent an event that either caused harm or was significant enough to potentially cause harm. The specific types of errors associated with those events, including documentation errors and errors of omission as opposed to errors of commission, are shown in Table 2. Table 3 shows the percentage of PMEs according to several patient and site factors and the unadjusted association between each factor and PME.

Table 2 Categorization of preventable medical errors by type of event and types of error

Type	No documentation error (*n*)	Documentation error (*n*)	Total (*n*)
Preventable AEs			
Non-medication	1	0	1
Medication-related	3	0	3
Non-intercepted NMs			
Error of commission	14	21	35
Error of omission	5	0	5
Intercepted NMs	6	21	27
Total	29	42	71
NM error examples			
Non-intercepted NMs			
Error of commission, with documentation error			
"Multiple unsigned and untimed orders for cardiac meds."			
Error of commission, without documentation error			
"Epinephrine 0.3mg SQ given by nurse x2. Ordered by MD one stacked."			
Error of omission, without documentation error			
"No Heparin in STEMI."			
Intercepted NMs (*N.B. intercepted NMs are all errors of commission*)			
With documentation error			
"Heparin ordered without dose/route/frequency."			
Without documentation error			
"Beta blocker ordered when pulse low, but not given."			

AE adverse event, *NM* near miss

Table 3 Patient encounters with any preventable medical error, according to demographic factors, diagnosis, site and crowding exposure

	n	% PME	Unadjusted OR (95% CI)
Age (years)			
14–17	23	4.4	0.73 (0.09–6.00)
18–40	171	5.9	Reference
41–64	192	8.9	1.56 (0.70–3.52)
65+	147	12.2	2.25 (1.00–5.03)
Gender			
Male	271	10.3	Reference
Female	258	7.0	0.64 (0.35–1.18)
Language			
English speaker	501	8.6	Reference
Non-English speaker	31	9.7	1.14 (0.33–3.91)
Diagnosis			
Asthma exacerbation	220	3.6	Reference
Acute myocardial infarction	210	11.0	3.26 (1.42–7.46)
Dislocation	103	14.6	4.52 (1.85–11.04)
Site			
1	157	14.7	Reference
2	105	12.4	0.82 (0.40–1.71)
3	174	4.0	0.24 (0.10–0.59)
4	97	3.1	0.19 (0.05–0.64)
Crowding quartile[a]			
1	136	6.6 (3.1–12.2)[b]	Reference
2	131	9.2 (4.8–15.5)[b]	1.42 (0.58–3.50)
3	134	4.5 (1.7–9.5)[b]	0.66 (0.23–1.91)
4	132	14.4 (8.9–21.6)[b]	2.37 (1.03–5.46)

PME preventable medical error, *OR* odds ratio, *CI* confidence interval

[a] Please see "Methods" section for details

[b] Binomial exact 95% confidence intervals

Main results

The multivariable logistic regression analyses showed that patients whose average crowding exposure was in the highest quartile had >twofold increased odds of experiencing a PME relative to patients whose average crowding exposure was in the lowest quartile (Table 4). Further controlling Model 1 for the site of the patient encounter did not substantively change this result (adjusted OR 2.44; 95% CI 1.03–5.81). To decrease the number of factors in the multivariable model, Model 2 examined the highest crowding exposure quartile versus the other three quartiles combined and yielded very similar results (Table 4). In all analyses, patients with acute myocardial infarction or dislocation had significantly greater risk of experiencing a PME than patients with asthma exacerbation.

Our secondary analyses also looked at the type of PME. Of the 46 patients who experienced a PME, only 4 patients experienced a preventable adverse event, precluding further analysis of these events, while 44 patients experienced some form of near miss (patients may have experienced multiple PMEs). Of those 44 who experienced a near miss, 25 experienced an intercepted near miss, 29 experienced a non-intercepted near miss, with 10 experiencing a combination of these. The OR for any near miss within the highest crowding quartile was statistically significant (adjusted OR 2.48; 95% CI 1.28–5.82), as was the OR for intercepted near misses in that same quartile (adjusted OR 2.39; 95% CI 1.01–5.37). The OR for non-intercepted near misses was of similar magnitude but not statistically significant (adjusted OR 2.17; 95% CI 0.98–4.80).

Discussion

While the medical literature contains examples of ED crowding causing delays in care, our study is the first to find an association between ED crowding and PMEs. The association was present for the composite outcome, as well as its components (preventable adverse events, non-intercepted near misses, and intercepted near misses). This might partly explain the etiology of adverse patient outcomes in patients exposed to ED crowding, since they might be due not only to delays in time-sensitive care, but also to actual medical errors that occur during periods of greater crowding [1, 2, 4–9].

Table 4 Multivariable logistic regression of emergency department crowding and the occurrence of any preventable medical error

	Model 1			Model 2		
	Odds ratio	95% confidence interval		Odds ratio	95% confidence interval	
Crowding quartile						
1 (least crowded)	1	Reference				
2	1.53	0.61	3.81	1[a]	Reference[a]	
3	0.67	0.23	1.96			
4 (most crowded)	2.36	1.01	5.48	2.28	1.19	4.38
Diagnosis group						
Asthma exacerbation	1	Reference		1	Reference	
Acute myocardial infarction	3.26	1.42	7.49	3.13	1.35	7.27
Dislocation	4.50	1.82	11.10	5.12	2.04	12.88
Site						
1				1	Reference	
2				0.79	0.37	1.67
3				0.22	0.09	0.54
4				0.17	0.05	0.59

[a] This represents crowding quartiles 1–3 combined

Although statistical power was limited in this pilot study, the results suggest a non-linear effect of patient crowding upon PMEs. It would appear that some crowding is relatively well tolerated, but there is a breaking point at which more PMEs occur. Given the nature of the ED care environment and providers' multitasking, this suggests that there may be a limit to the number of tasks to which ED providers may attend before beginning to commit errors [34, 35].

Most of the PMEs identified were near misses, rather than preventable adverse events, and the majority of the near misses were intercepted. As noted earlier, all of these were considered significant errors. Some might be tempted to interpret this as a tribute to ED systems: that during times of crowding many of these near misses were intercepted as opposed to non-intercepted, and that actual adverse events may have been prevented. However, we consider any preventable medical error concerning, including intercepted near misses [36]. A recent study of medication errors in the ED finds that 80% are intercepted, with more than half of the significant errors judged as serious or potentially life threatening [37]. Crowding in the ED may exacerbate the rate of medical errors and their severity [35, 38, 39]. As safety systems fail, intercepted near misses may become preventable adverse events. Such errors may also point to systematic flaws at the point of health care delivery that should be reengineered to mitigate inevitable human failures [36].

Within the three diagnosis groups, we found that most errors occurred in patients with dislocations requiring procedural sedation, and the fewest in patients treated for asthma; patients with acute myocardial infarction were at intermediate risk. This has face validity—asthma care for most patients is relatively straightforward, and acute myocardial infarction, while more complex, is the most time-sensitive condition and often treated using explicit guidelines to ensure compliance with standards of care. Dislocations requiring procedural sedation are less time sensitive, but require vigilance in managing both the dislocation and the sedation.

Finally, our data suggest significant differences between the risk of a medical error and the site in which the patient was seen. This heterogeneity across sites might be due to several factors. Direct comparison of crowding data across institutions is difficult, and it is possible that our study sites had wide variations in crowding. It is possible that the sites vary in overall patient acuity, but it is also possible that variations in clinical practice, patient management, and staffing levels play a role. To explore these possibilities, further studies, with larger samples, are needed to determine those practices that best protect patients.

Limitations

Our study has several limitations. We used a convenience sample of four local EDs in a major metropolitan area that participated in NEDSS, and a random sampling of EDs might have yielded different results. We chose to set the crowding exposure to the average exposure the patient experienced in the ED as NEDSS did not report an exact time a PME occurred, and it is possible that patients experienced PMEs during the least crowded portion of

their ED encounter, though this is unlikely. We were unable to compare crowding across the EDs, as there is no universally accepted benchmark for what represents a crowded ED, and no uniform method to compare crowding across EDs, even with a single crowding measure (e.g., does 75% occupancy in one ED "feel" as crowded as in another?). We were further limited by the lack of a common crowding measure that could be reliably applied to all the participating EDs. As all three crowding measures we used have been independently validated, found to be comparable, and because we examined quartiles of crowding within a single metropolitan area, we believe this approach permits comparisons across sites. We cannot, however, determine an absolute crowding threshold at which the risk of PMEs significantly increases.

Our results are also limited by our relatively small sample size and the relative paucity of errors that occurred. We were unable to analyze the exact nature of the error for errors of omission (7% of our errors) in which a required action was not documented, though each error was judged significant by experienced physicians.

Finally, we did not analyze any non-preventable adverse events that occurred since, by our definition, they do not represent errors. We acknowledge that some non-preventable adverse events may be due to delays in care. These events might be considered preventable if we broaden our understanding of emergency care to encompass adverse events not only caused by the actions or inactions of individuals, but also the overall conditions of the health care environment in which those individuals work. While it was beyond the scope of this study to address this issue, such an approach might have increased the risk of PMEs that we reported.

Conclusions

This study identifies a direct association between high levels of ED crowding and PMEs. Our study was limited by our relatively small sample size and number of events that occurred; the generalizability of our findings will require study of additional conditions other than the three examined here, with larger numbers of diverse EDs and patient encounters. Should such research confirm our findings, we would suggest that mitigating ED crowding may reduce the occurrence of preventable medical errors.

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Conflict of interest None.

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